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THERMAL PERFORMANCE OF WICKLESS HEAT PIPE WITH METHANOL AND ETHANOL WORKING FLUIDS

Hussain Saad Abd, Hisham Assi Hoshi, Abdulmunem R. Abdulmunem
Electromechanical Engineering, University of Technology, Baghdad, Iraq

ABSTRACT

A wickless heat pipe is fabulous warm exchange devices that their integration into warm exchangers has been appeared a strong potential for energy investment funds. In the present work, the performance characteristics of wickless heat pipe such as; thermal power, working fluids, variation of temperature with different powers, thermal resistance and heat transfer coefficient are being investigated experimentally. ethanol and methanol was being utilized as working fluids with filling ratio of 50%, with different thermal loads (20, 30, 40, 50 and 60W), and constant flow rates of cooling water (1 l/min). A copper tube of outer diameter of 22mm was fabricated as wickless heat pipe. The lengths of the evaporator, adiabatic and condenser sections are 500mm for each section. Within the tests, the temperature dissemination on the wickless warm pipe surface and the temperature contrasts of the cooling water were measured. The information were utilized to calculate the warm resistance and heat transfer coefficient for each analyzed working fluid; results are displayed graphically and examined in detail. These results demonstrated that ethanol is the working fluid that has the most excellent thermal performance.

Key words: Wickless Heat Pipe, Thermal performance, Methanol, Ethanol.

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1. INTRODUCTION

Wickless warm pipes are inactive two-phase warm exchange gadgets. Warm connected to the evaporator segment vaporizes working fluid which at that point rises to the condenser area. At condenser section, vapor relies its heat of vaporization and condensate, and at that point flows back to the evaporator area due to gravitational drive. Cycle of evaporation and condensation proceeds as warm is connected at evaporator and rejected at the condenser [1]. They are utilized for numerous applications counting against solidifying [2], warm exchangers in squander warm recuperation applications, preparing broilers, [3], water radiators and sun

powered vitality frameworks [4], and appearing a promising solution for high-performance electronics thermal management [5].

Many researchers studied the thermosyphons with different parameters such as Khazaee [6] studied the thermal performance of two copper tubes with different internal diameters (15and 25mm) and length of 1000mm with ethanol as working fluid were used. The a good agreement between experimental and literature correlations for boiling, condensation and heat transfer coefficient on performance of thermo syphon was showed in the results, also they proposed empirical correlation for boiling heat transfer coefficient.

while, Kannan et al. [7] used (water, ethanol, methanol, and acetone) as working fluids with filling ratio between (30 to 90%) in a three tubes with different diameters (6.7, 9.5 and 12mm) and wall thickness 0.65mm, to study the effect of various parameters of two-phase thermosyphon on its thermal ability. Each tube has length of (1000 mm), consisted evaporation section with 300mm, adiabatic section with 200mm and condensation section with 500mm. Electric heater supplied heat to the evaporator, while the condenser cooled by water in tube heat exchanger. It seen that the best heat transfer capability of working fluids was water, while the lowest heat transfer capability was acetone.

A small inner diameter (6 m meter) of copper thermosyphon with water and dielectric working fluids (FC-84, FC-77 and FC-3283) was studied by Jouhara et al. [8].Tube length are (200 m meter) and evaporation section and condensation were (40 and 60 m meter), respectively. Experiments showed that despite the benefits of using dielectric fluid, but water was the best capability of heat transfer.

Ong et al. [9] worked on power input, filling ratio and tilt angle. They used (R-410A) refrigerant as a working fluid in a copper thermo syphon with (930 m meter) length. The internal diameter was (9.5 m meter) with outer diameter was (12.7 m meter), and equally length for evaporation, condensation, and adiabatic sections. Heat supplied to evaporator section by an electric heater, while condensation section cooled by heat exchanger with water as a coolant.

MacGregor et al. [10] studied the performance of thermosyphon with three fluids were chosen, water, methanol, and (5%) ethylene glycol-water mixture. The mixture of water and glycol was chosen to avoid problems associated with freezing. Thermosyphon was made of copper tube with 2200mm long and 15.9mm outer diameter. The internal surface was grooves to enhanced heat transfer. Hot and cold water was used as a heat source and heat sink. The experiments showed that water-ethylene glycol mixture could be a good replacement of (R134a) in thermosyphon. It should be also noted that for certain conditions its performance was lower than filled with (R134a).

This work aimed to study the performance characteristics of wickless heat pipe such as (variation of temperature with different powers, thermal resistance and heat transfer coefficient) using (50%) filling ratio of Ethanol and Methanol as working fluids with different thermal loads (20, 30, 40, 50 and 60W), and constant flow rates of cooling water (1 l/min).

2. METHODOLOGY

2.1. System Configuration

Figures (1and 2) appears the test setup of used thermo syphon and the schematic diagram of the experimental apparatus. Used thermosyphon are made from a copper tube that was (1200 m meter) long with internal and external distances across of (20.4 and 22 m meter), respectively. The thermo syphon are separated into three areas a (500m meter) long evaporator area at the bottom, (200m meter) long adiabatic area at the center, (500m meter) long condenser area at the top. At the evaporator area, warm are created by Niechrome wire

resistance (heater) with different thermal loads (20, 30, 40, 50 and 60W). The warm input are controlled utilizing variac. At the adiabatic area, the copper tube was disconnected to play down heat loss to the environment. Within the condenser area, a water coat was introduced to retain warm within the condenser and was associated to a circulating thermostatic shower to supply a steady temperature of cooling water at the channel area. Circulating thermostatic shower give cooling water at a consistent temperature of (21° centigrade) and mass flow rate of (1 Liter/min). A flow meter with exactness of (±4%) was utilized to degree the coolant mass flow rate within the water coat.

Methanol and ethanol are chosen as the working fluid at filling ratio of (50%). The thermosyphon system was insulated with glass fleece to diminish the warm misfortune. Preheating and vacuum forms were performed to evacuate broken up gas interior the thermo syphon within the working fluid.

The test information was recorded employing an information lumberjack framework. Eleven K sort thermocouples with an exactness of (±0.05 °C) were utilized on the thermo siphon exterior divider, three thermocouples on the exterior evaporator divider, one thermocouple on the exterior adiabatic divider, five thermocouple on the exterior condenser divider, one thermocouple on the coolant channel, and one thermocouple on the coolant outlet.

Figure 1 Experimental setup of the thermosyphon.

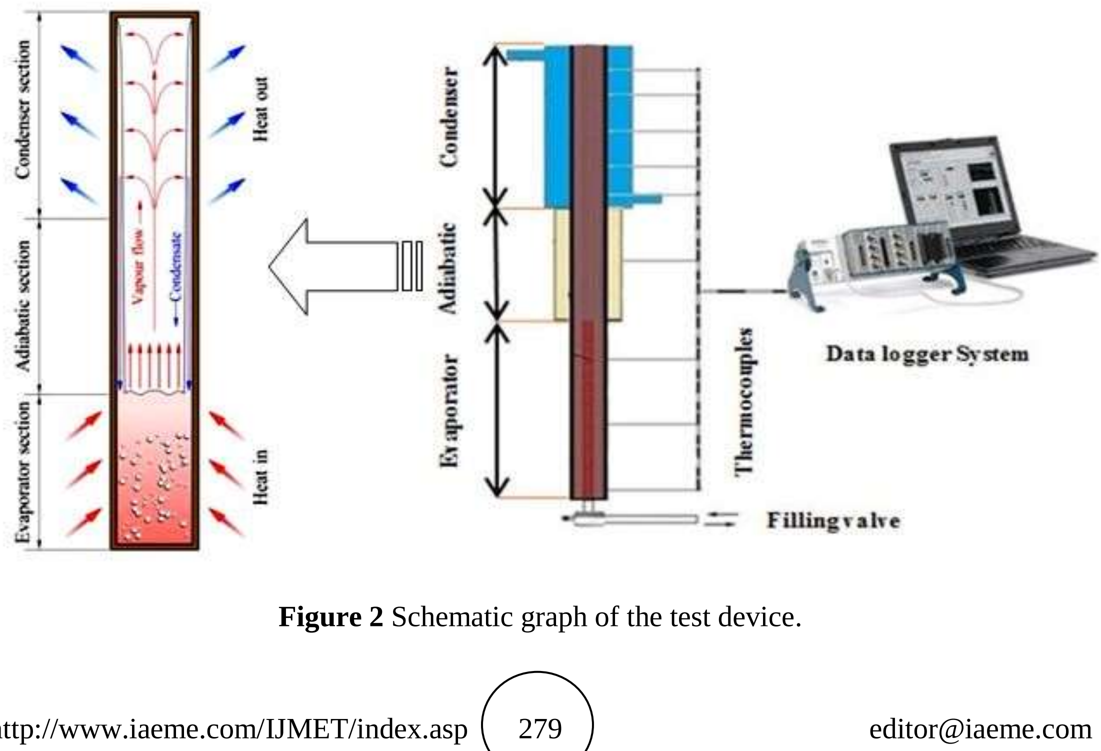


Figure 2 Schematic graph of the test device.

2.2. Experiment Procedure

Experiment part are separated into two steps; the first step are evacuated thermosyphon and the second step was charged it with the required filling ratio of the working fluid, which is (50%) with two different working fluid (methanol then ethanol). The properties of the two working fluids are shown in Table 1. Heat stack given to the evaporator area by variance are at (20, 30, 40, 50 and 60 W). Each power was applied for (12 mins) and the thermocouples values are recorded each (6 sec).

Table 1 Thermo-physical characteristic of working fluids [11]

Fluid	Molecular form	Ebullition temp. (1 atm)(^oC)	Latent heat of vaporization (kJ/Kg)	Profitable temp. area (^oC)	Thermal conductivity at 300K (w/m.K)	Viscidity (N.s/m^3)
Ethanol	C_2H_5OH	78.37	846	0 to 130	0.171	1.1980×10^{-3}
Methanol	CH_3OH	64.7	1100	10 to 130	0.202	0.544×10^{-3}

Utilizing the information gotten from the tests, the execution of the thermo syphon beneath an assortment of parameters, such as working fluid and connected warming control input, was decided utilizing the following:

2.3. Governing Equations

Heat load inside the evaporator section is defined as follows, [12, 13]:

$$Q_{in.} = V.I \quad (1)$$

Sum of warm exchange to the cooling fluid, [14]:

$$Q_{out.} = \dot{m}_w\, c_p\, (T_{w,o} - T_{w,i}) \quad (2)$$

Variations within the temperatures of the cooling water at the channel and outlet of condenser, mass flow, and fixed warm values of water were utilized in calculating.

The warm exchange capacity of evaporator area is decided by the dissipation warm exchange coefficient (h_e). From the measured information of divider temperature and vapor temperature (identical to the divider temperature of the adiabatic area), the warm exchange coefficient within the evaporator can be assessed utilizing the taking the eq.:

$$h_e = \frac{Q_{ave.}}{\pi\, D_i\, L_e(T_{e,ave} - T_v)} \quad (3)$$

Where:

$$Q_{ave.} = \frac{Q_i + Q_o}{2} \quad (4)$$

The warm exchange capacity of the condenser area is additionally reflected through condensation heat transfer coefficient (h_c). This can be related with conduction through the fluid film interior the thermosyphon and related to the normal divider temperature of condenser area which can be assessed utilizing the eq.:

$$h_c = \frac{Q_{ave.}}{\pi\, D_i\, L_c(T_v - T_{c,ave})} \quad (5)$$

In the evaporator and condenser area, respectively, thermal resistance is calculated by:

$$R_e = \frac{T_{e,ave} - T_v}{Q_{ave.}} \quad (6)$$

$$R_c = \frac{T_v - T_{c,ave}}{Q_{ave.}} \quad (7)$$

The proportion of the warm catapulted from the condenser to the warm gotten from the evaporator was defined as the efficiency of the thermosyphon, and it was calculated as:

$$\eta = \frac{Q_o}{Q_i} \tag{8}$$

2.4. Instability Analysis

The instabilities of the measurement instrument applied in this test was given as follow:

The instability of evaporator section's thermal resistance (Re) can be found by;

$$\frac{\Delta R_e}{R_e} = \sqrt{\left(\frac{\Delta\, Q_{ave.}}{Q_{ave.}}\right)^2 + \left(\frac{\Delta\,(T_{e,ave} - T_v)}{T_{e,ave} - T_v}\right)^2} \tag{9}$$

Where $\Delta\, Q_{ave.}$, and $\Delta\left(T_{e,ave} - T_v\right)$ are the instabilities of input warm from framework boundary, and the temperature contrast between the normal divider temperatures at evaporator area and adiabatic area, separately.

The instability of evaporator section's heat transfer coefficient h_e can be defined as;

$$\frac{\Delta h_e}{h_e} = \sqrt{\left(\frac{\Delta\, Q_{ave.}}{Q_{ave.}}\right)^2 + \left(\frac{\Delta\,(T_{e,ave} - T_v)}{T_{e,ave} - T_v}\right)^2} \tag{10}$$

Similar instability do to condenser section for thermal resistance (R_c) and condenser section's heat transfer coefficient (h_c).

Greatest instabilities of the warm exchange coefficient, the warm resistance of evaporator and condenser areas of wickless warm pipe are calculated and displayed within the Table 2.

Table 2 The uncertainties of studied parameter

Parameter	Maximum instability
$\boldsymbol{R_e}$	8.05%
$\boldsymbol{h_e}$	10.82%
$\boldsymbol{R_c}$	7.1%
$\boldsymbol{h_c}$	6.03%

3. RESULTS AND DISCUSSION

The results of thermal performance for different working fluids (ethanol and methanol) in wickless heat pipe were investigated with different thermal loads (20 , 30 , 40 , 50 and 60W).

In Figures 3, the temperatures distributions over the thermosyphons are presented for ethanol and methanol working fluids for the used different thermal loads.

It can be noted from this figure, that at each test all temperatures began from the ambient then after that evaporator and adiabatic positions increased according to the heat added at evaporator position, where the condenser position stay constant according to cooling water at this section.

A Figure 4 shows the comparison between ethanol and methanol working fluids at the same thermal loads. It’s clear that temperature decreases along length of wickless heat pipe, and have high value at high thermal load; this value decreased with decreasing thermal load. Evaporator position shows large temperature. At low thermal load, 20W liquid start to vaporize and at this case greatest working liquid is in fluid state and bubbling restrain shows up. When warm stack expanded to 60W, greatest fluid gets vaporize and exceptionally little parcel of fluid stay within the evaporator. This will lead to flooding impediment. At the same

time we can note that temperature for ethanol is higher than that of methanol, which according to high Boiling point for ethanol.

Execution of wickless heat tube denoted by thermal impedance and heat transmit coefficient, Figure 5a show thermal resistance at evaporator and condenser sections R_e, R_c for ethanol working fluid as function to thermal load. As we seen, operating temperature increment and thermal resistance decreases with increase thermal load.

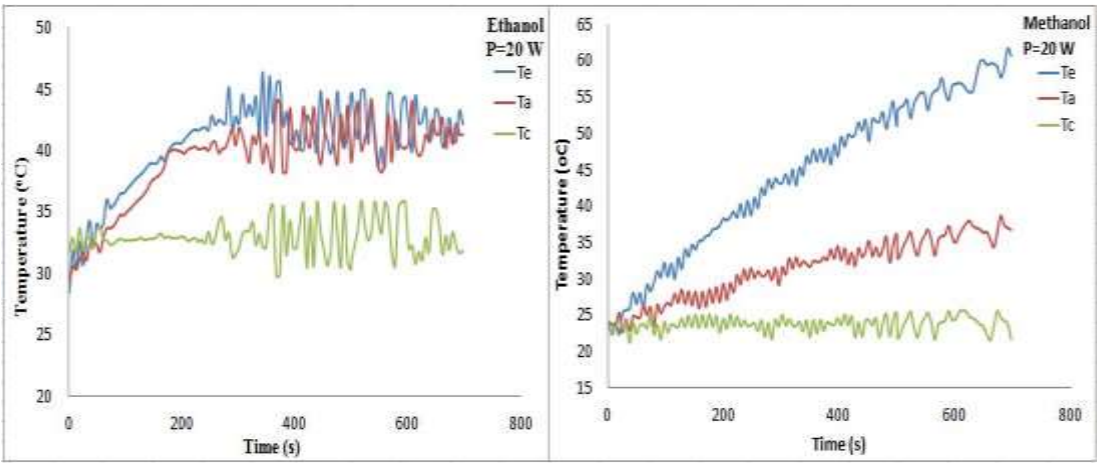
Figure 5b exhibits heat transmit coefficient at evaporator and condenser area (h_e , h_c) against thermal load. The heat transfer coefficient shows an increment with rising thermal load. Thermal impedance of evaporator area is bigger that of condenser area, that's beyond to heat transfer coefficient at condenser section larger that of evaporator section.

Figure 6 illustrate the various of overall thermal impedance of wickless heat tube with applied thermal load for methanol and ethanol working fluids. It is obvious that with the increase of thermal loads, overall thermal resistance for two working fluids reduction significantly. Ethanol was appearing the lowest overall thermal Impedance with thermal loads because it has lowest latent heat of vaporization with a saturated boiling temperature of (846 ^{o} centigrade). At a lower thermal load, the liquid ethanol has quickly varied into a vapor. For other liquids methanol, evaporation process takes longer time because they have higher vaporization latent heat and boiling points. A faster phase varied from liquid-vapor-liquid for ethanol produces a low thermal impedance comparison to other liquid. Between analyzed thermosyphons, ethanol is the working fluid that presents the best thermal performance.

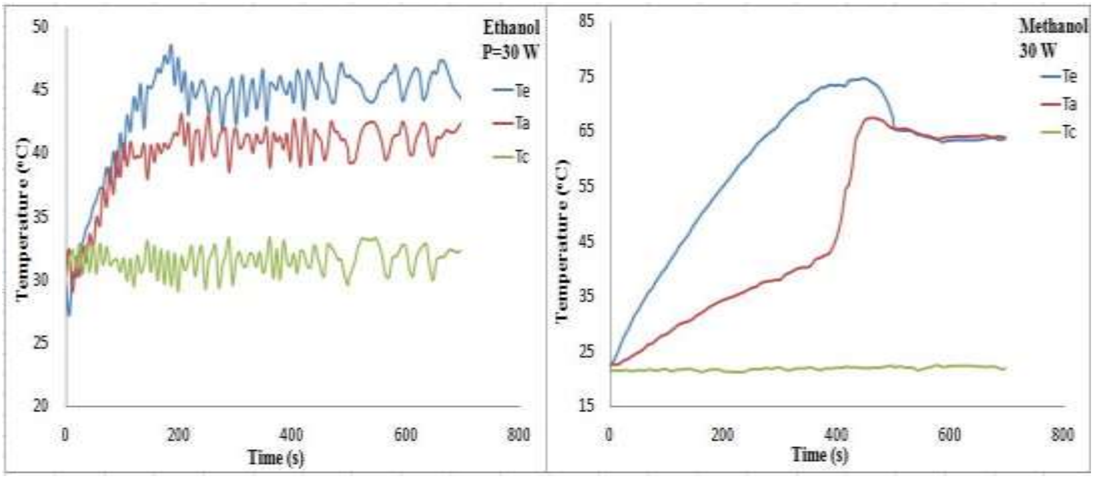
4. CONCLUSIONS

In this experiment it can conclude the following:

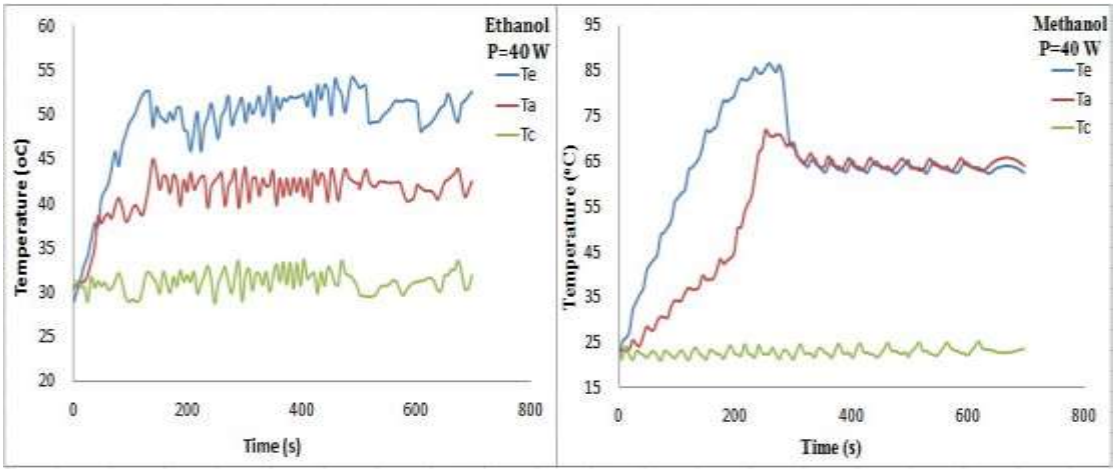
- Wickless heat pipe has satisfactory heat transfer coefficient so has its own importance in low temperature difference heat transfer and its performance is depends on the phase change working fluid.
- Different working fluids used in various wickless heat pipes according to its application in various areas. In this experiment ethanol and methanol used as working fluids.
- The working fluid with better thermal performance was ethanol.



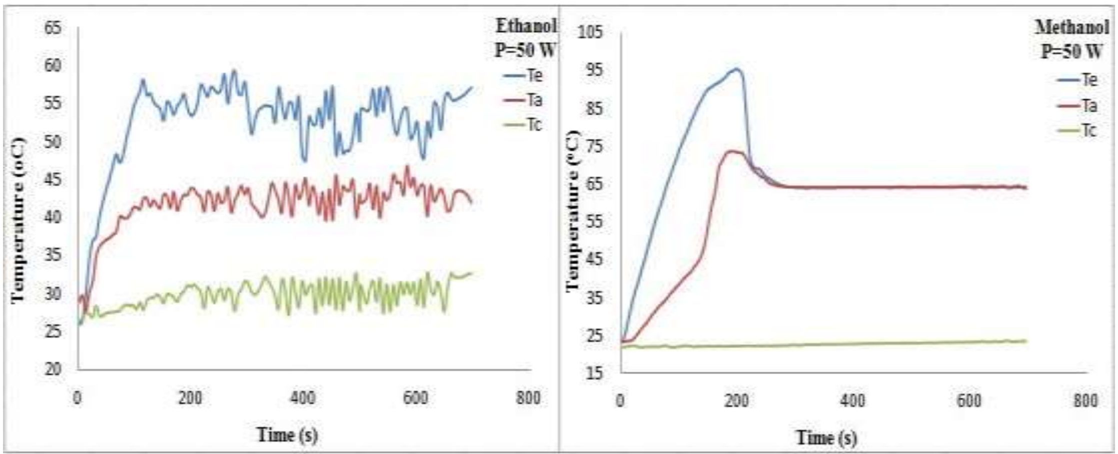
(a)


Ethanol
P=30 W
Te
Ta
Tc
Temperature (°C)
Time (s)
Methanol
30 W
Te
Ta
Tc
Temperature (°C)
Time (s)

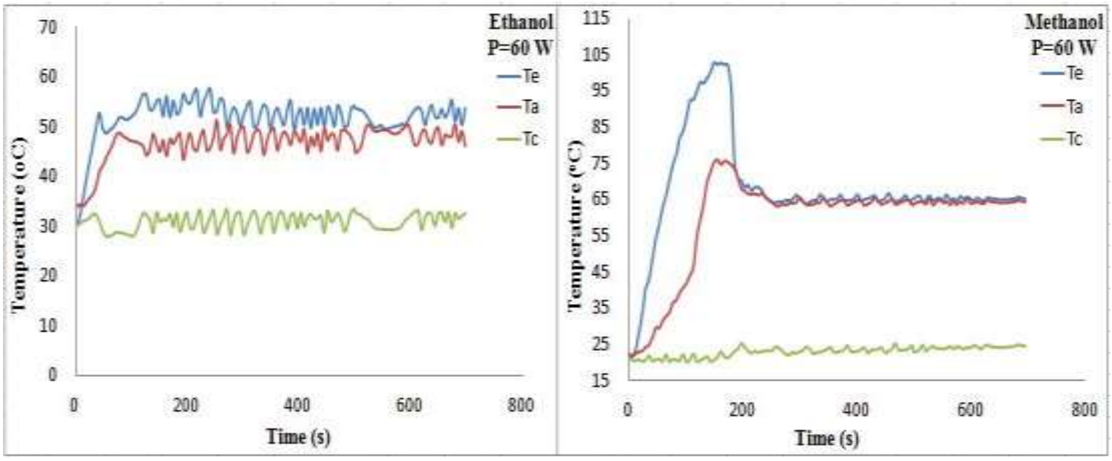
(b)


Ethanol
P=40 W
Te
Ta
Tc
Temperature (oC)
Time (s)
Methanol
P=40 W
Te
Ta
Tc
Temperature (°C)
Time (s)

(c)


Ethanol
P=50 W
Te
Ta
Tc
Temperature (oC)
Time (s)
Methanol
P=50 W
Te
Ta
Tc
Temperature (°C)
Time (s)

(d)



(e)

Figure 3 Temperature distributions of wickless heat pipe versus time for ethanol and methanol working fluids for different thermal loads from (a) 20W to (e) 60W.

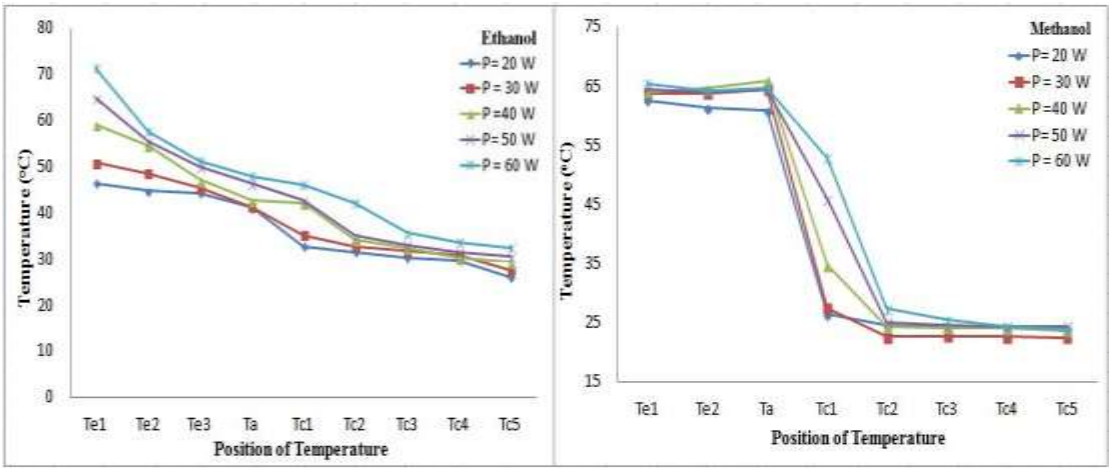
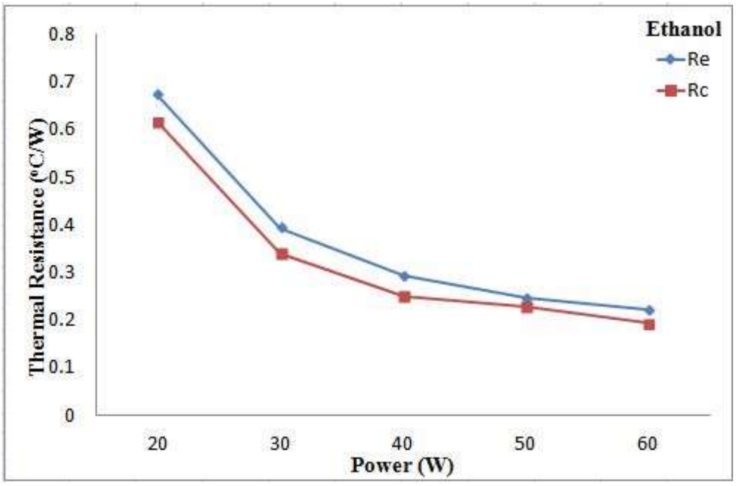
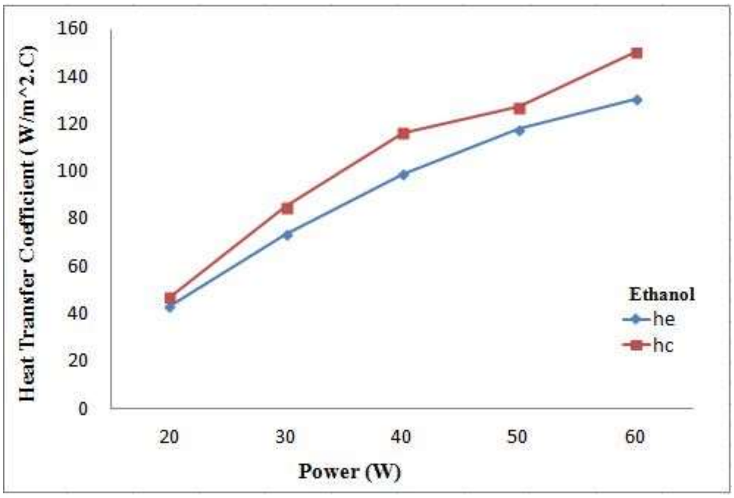


Figure 4 Comparison between temperature distributions along wickless heat pipe for ethanol and methanol working fluids.



(a)



(b)

Figure 5 (a) Thermal resistance versus applied power (b) Heat transfer coefficient versus applied power, for Ethanol working fluid.

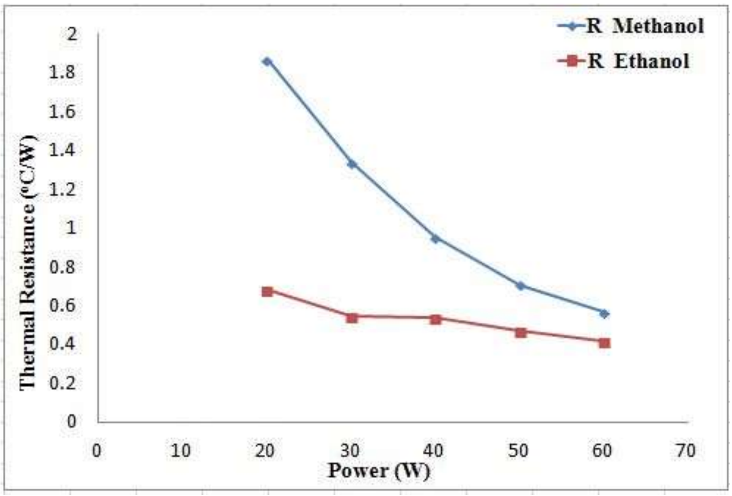


Figure 6 Over all thermal resistance versus applied thermal load for methanol and ethanol working fluids.

Nomenclatures		Subscripts	
CP	Specific heat	ave	Average.
D	Diameter, (m)	c	Condenser.
h	Heat transfer coefficient,(W/m^2.K).	c, ave	Average to the condenser section.
I	Current, (A)	e	Evaporator.
k	Thermal conductivity, (W/m.K).	e, ave	Average to the evaporator section.
L	Length, (m).	i	Inlet.
$m^{\cdot}$	Mass flow rate.	l	Liquid phase of the working fluid.
Q	Thermal heat load,(W).	o	Out let.
R	Thermal resistance, (^{o}C /W).	v	Vapor phase of the working fluid.
T	Temperature.	w, i	Cooling fluid, out let.
V	Voltage, (v).	w, o	Cooling fluid, out let.
η	Efficiency of the thermosyphon.		

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